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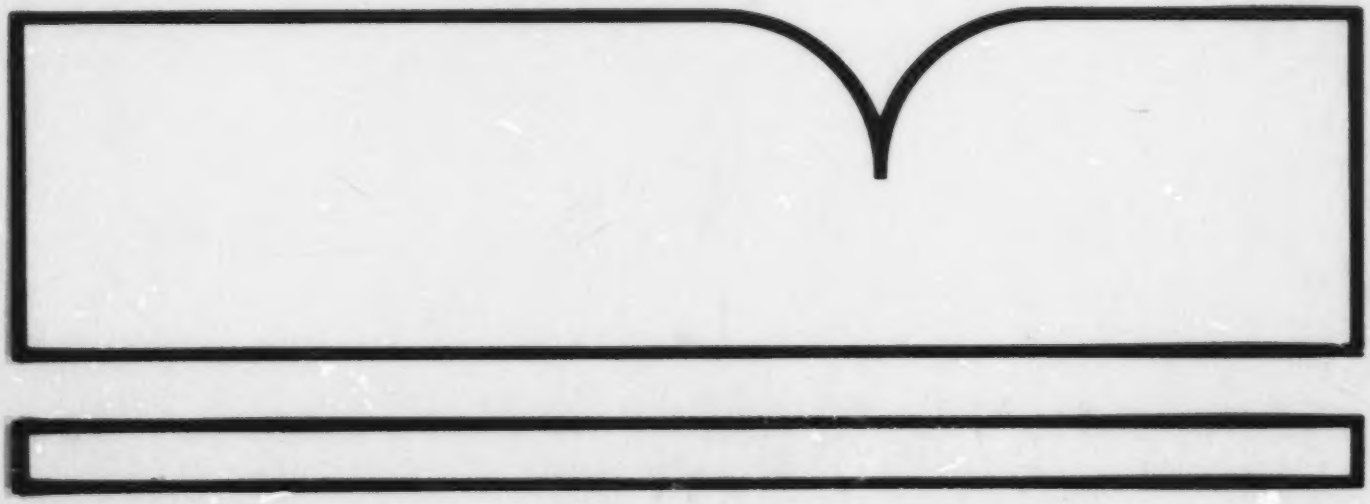

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The direct effects of acidic precipitation on vegetation are becoming increasingly better understood. The indirect consequences of both acute and chronic exposure of vegetation to acidic precipitation are very complex, however. Their effect is variable in time, and involves a variety of potential interactions which are only partially understood.

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EFFECTS OF RAINFALL ACIDIFICATION ON PLANT PATHOGENS

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INTRODUCTION

Wind-blown rain, rain splash, and films of free moisture play important roles in the epidemiology of many plant diseases. The chemical nature of the aqueous microenvironment at the infection court is a potentially significant factor in the successful dissemination, establishment, and survival of plant pathogenic microorganisms. Acidic rainfall has a potential for influencing not only the pathogen, but also the host organism, and the host-pathogen complex. Although host-pathogen interactions add a degree of complexity to the study of abiotic environmental stress of plants, it is our hope, through the use of a combination of general concepts, theoretical postulations, and experimental data, to describe the potential role that rainfall acidity may play in the often subtle balance between populations of plants and populations of plant pathogens.

The direct effects of acidic precipitation on vegetation are becoming increasingly better understood[1,2]. The indirect consequences of both acute and chronic exposure of vegetation to

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acidic precipitation are very complex, however. Their effect is variable in time, and involves a variety of potential interactions which are only partially understood[3].

MECHANISMS BY WHICH ACIDIFICATION MIGHT INFLUENCE THE DISEASE PROCESS

Based on a generalized disease cycle typical of many plant diseases, we can hypothesize particular stages in that disease cycle where the stress of acid rain might be of greatest significance to disease development. These include:

1. The primary inoculum over winters in plant debris, reproduces asexually in crop residues moistened by spring rains. Spores are disseminated by wind-blown rain and water splash.

2. The spore lands on susceptible host tissue. Free moisture on the leaf surface is essential to spore germination, and external growth prior to penetration.

3. Penetration of the host occurs directly through a primary host barrier to penetration, the cuticle, or through stomatal openings, or through wounded tissues.

4. Colonization occurs in host tissues. The pathogen is "buffered" by host tissues, and less directly influenced by external environmental factors, and thus more dependent on host metabolism.

5. Secondary inoculum is produced in infected tissues, disseminated by wind-blown rain and water splash.

6. High humidity, and free moisture on leaf surfaces favors development of an epidemic.

7. Inoculum persists over winter in crop residues.

Certainly, this is a generalized and simplified example of a disease cycle, yet in each of the stages involved, we see clear potential for the chemical composition of rainwater to play a significant role in the development of tne disease interaction. In stages one, two, five, and six, the pathogen is in intimate contact with a solution which may, because of its acidity, or other chemical constituents, be inhibitory to the pathogen. In stages three and four, the possible direct effects of rain acidity on the host plant include: (a) advanced weathering of the cuticular defense barrier[4,5]; (b) interference with normal

function of guard cells[6], and hence, potentially altered stomatal penetration; (c) direct injury, with potential invasion of wounded tissues[7]; and (d) potential leaching of water-soluble spore germination inhibitors from host tissues[8].

In all stages of the disease cycle, other direct and indirect effects on the host plant may dramatically influence the fitness, or disease-proneness of that host. Among these possible additional effects are included:

1. Non-symptomatic disturbance of normal carbon and nutrient metabolism, including alteration of leaf and root exudation processes, and accelerated leaching of nutrient elements from foliage.

2. Synergistic interactions with other environmental stress factors, such as gaseous air pollutants (SO_2, O_3, etc.), light and temperature.

We will focus on many of the above potential phenomena, and review the evidence to date to support or reject the hypothesis that acidic rains may significantly affect plant-parasite interactions.

CASE EXAMPLES: EVIDENCE FOR AN EFFECT

If we pursue the disease-cycle analogy, we can examine step-by-step evidence for the potential interaction of acidic rain with plant disease processes:

Inoculum Dissemination

Virtually hundreds of species of fungi and bacteria are disseminated by rain splash and wind-blown rain[9]. The inability of many bacteria to survive, or remain infective in acidic media is also well established[10]. The relative resistance of bacteria, yeast, and mold fungi to acid conditions is reported to be in the approximate ratio of 1:4:5 respectively.

Leben[12] has investigated the use of acidic buffer sprays for their potential usefulness as disease control agents. In that work, Leben demonstrated that when acidic buffer sprays were applied to tomato foliage prior to inoculation with Alternaria solani (Ell. and Mart.) Jones and Grout, reductions in incidence of early blight were 53-79 per cent. Yarwood[13] has also described therapy of certain powdery mildews due to acidic conditions on the leaf resulting from applications of sulfuric, nitric, and acetic acids. In separate experiments with acidified

media, Leben[12] reported significant growth reductions on nearly all of 15 species of plant pathogenic fungi at pH 4.1 and severe growth reductions on all 15 species at pH 3.2.

In experiments with simulated acidic rain, Shriner[14] found the acidity of the water in which the inoculum was disseminated significantly influenced the subsequent success of the bacterial bean pathogen, Pseudomonas phaseolicola (Burkh.) Dows. Bacteria which remained in an infection droplet of pH 3.2 for as little as 2 hours were found incapable of infecting either healthy or acidic rain-injured bean foliage.

Host Defenses

Substantial volumes exist[15,16,17] which review the role of the plant cuticle and epicuticular waxes as barriers to penetration by plant pathogens. Martin and Juniper[15] and Purnell and Preece[8] discuss the weathering of epicuticular waxes on leaf surfaces by rain. Purnell and Preece concluded that little of the wax removed by rain from mature, fully expanded leaves is regenerated. Other data[5] suggest that at least for one species, willow oak, the rate at which the weathering of the leaf surface progresses may also be a function of the acidity of the rainfall impacting that surface.

The significance of the weathering of the leaf surface in terms of plant disease development is several-fold:

(1) Weathered surfaces may actually pose a less formidable mechanical barrier to direct penetration by pathogens.

(2) Weathered surfaces increase in wettability[15]. This increase in wettability may subsequently result in significantly greater numbers of water-borne propagules being retained on the leaf surface in a position to effect successful penetration[15].

(3) Weathered leaf surfaces have been shown to have increased retention of certain fungicides[15], and other particulates[18]. (Weathering also makes a wide range of plant cuticles more permeable to weed killers[15].)

A different type of effect on host defense barriers potentially induced by acid rains is the creation of infection courts on the leaf surface as the result of direct injury to leaf tissues. Such direct, visible injury may occur from exposure to rainfall acidity at pH 3.4 or below[2]. Shriner[14] found disease severity increased when beans inoculated with P. phaseolicola had

been predisposed by exposure to simulated rains of pH 3.2. Numerous small necrotic lesions were thought to have provided the pathogen with increased opportunity for penetration of the host tissues.

For those organisms which are facultative parasites, the added stress of acid precipitation would appear to provide the necessary advantage to the pathogen to result in successful penetration and colonization. From other data[14], however, obligate parasites (whose fortunes are more directly dependent upon those of the host) appear to be inhibited in their disease development by the stress of acidic rain on the host plant. Such an effect may have been the indirect result of imbalanced host metabolism.

The Disease Interaction

Several lines of evidence have been developed in recent years for the indirect effect of gaseous air pollutants on plant disease development as a result of effects on host plants[19]. Changes in the chemical composition of foliage, e.g., sulfur content, pollutant-induced production of phytoalexins, and altered supplies of metabolites are suggested mechanisms by which the growth and development of the pathogen within the host may be affected[20,21,22].

No direct evidence of similar effects has been reported for acidic rain/host-parasite interactions. However, observations of Shriner[14,23] of effects on root-knot nematode infection of Phaseolus vulgaris 'Red Kidney' and Rhizobium nodulation of the same species by simulated acid rain could be accounted for by alterations in host physiology induced by simulated rain of pH 3.2.

Other Factors Influencing Interaction of Acid Rain with Plant Disease Development

Several researchers have suggested the importance of dry particulate deposition on foliar surfaces in relation to disease incidence. Cement kiln dust deposits have been reported to increase the incidence of a fungus leaf-spot on sugar-beet leaves[24], and limestone processing dust appeared to stimulate leaf spot infections on wild grape and sassafras leaves.

Smith and Dochinger[25] have reported that leaf surfaces of trees lining urban streets contained greater than normal burdens of certain particle-borne metal contaminants and that these particles were effectively retained by the leaf surfaces. Other

works by Lindberg et al.[26] have shown similar retention of fly ash particles by leaf surfaces in a more remote forest canopy.

The potential would appear to be great for particles lodged on leaf surfaces to interact chemically with either ambient gaseous pollutants, or precipitation. Such particles could effectively increase the surface area of leaves available for reaction with gaseous pollutants, and, depending upon their source, either neutralize, or further acidify rain water contacting the leaf surface. While the ultimate effects of such particle-leaf interaction on plant disease processes are currently unknown, such interactions certainly occur in nature, and may be important in the final response of a plant to complex mixtures of air pollutants and plant pathogens.

SUMMARY

During the process of dispersion, deposition, and initial growth on the leaf surface, plant pathogenic fungal spores and bacteria are quite vulnerable, and often at the most tenuous phase of their life history. The data reviewed suggest that acid rain in the leaf surface microenvironment can be a critical factor in disease establishment. Understanding the positive and negative potentials of these interaction phenomena in field situations remains a challenge to our ultimate understanding of the effects of all forms of biotic and abiotic stress on plant growth and yield.

REFERENCES

1. J. N. Galloway, and E. B. Cowling. J. Air Poll. Cont. Assoc. 28:229 (1978).

2. J. S. Jacobson, and P. Van Leuken. Proc. Fourth Inter. Clean Air Congress, Tokyo, May 16-20 p.124 (1977).

3. C. O. Tamm, and E. B. Cowling, Water, Air and Soil Poll. 7:503 (1977).

4. D. S. Shriner, Ph.D. Thesis, N.C. State Univ., Raleigh, N.C., 79 p. (1974).

5. D. S. Lang, D. S. Shriner, and S. V. Krupa, Proc. 71st Ann. Mtg. APCA, Houston, Paper #78-7.3 (1978).

6. L. S. Evans, N. F. Gmur, and F. DaCosta, Amer. J. Bot. 64:903 (1977).

7. D. S. Shriner, M. E. DeCot, and E. B. Cowling, Proc. Am. Phytopath Soc. 1:112 (1974).

8. T. J. Purnell, and T. F. Preece, Physiological Plant Pathology 1:123 (1971).

9. J. C. Walker, "Plant Pathology", 2nd Ed., McGraw-Hill, New York (1957).

10. W. W. Umbriet, "Modern Microbiology", W. H. Freeman and Co., San Francisco (1962).

11. P. J. W. Saunders, in: "Ecology of Leaf Surface Micro-organisms", Academic Press, New York (1971).

12. C. Leben, Phytopathology 44:101 (1954).

13. C. E. Yarwood, Proc. 2nd Internat. Congr. Crop Protection, 22 p. (1951).

14. D. S. Shriner, Phytopathology 68:213 (1978).

15. J. T. Martin, and B. E. Juniper, "The Cuticles of Plants", St. Martin's Press, New York, (1970).

16. T. F. Preece, and C. H. Dickson, "Ecology of Leaf Surface Micro-organisms", Academic Press, New York (1971).

17. C. H. Dickinson, and T. F. Preece, "Microbiology of Aerial Plant Surfaces", Academic Press, New York (1976).

18. W. H. Smith, in: "Microbiology of Aerial Plant Surfaces", Academic Press, New York (1976).

19. A. S. Heagle, Ann. Rev. Phytopath. 11:365 (1973).

20. L. H. Weinstein, D. C. McCune, A. L. Alvisio, and P. Van Leuken, Environ. Pollut. 9:145 (1975).

21. W. J. Manning, W. A. Feder, P. M. Papia, and I. Perkins, Environ. Pollut. 1:305 (1971).

22. D. T. Tingey, and U. Blum, J. Env. Qual. 2:341 (1973).

23. D. S. Shriner, Env. Exp. Bot. (in press).

24. W. J. Manning, Environ. Pollut. 9:87 (1975).

25. W. H. Smith, and L. S. Dochinger, in: "Better Trees for Metropolitan Landscapes", Washington, D.C. (1975).

26. S. E. Lindberg, D. S. Shriner, R. R. Turner, and L. K. Mann, in: ORNL-5257 (1976).